MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2018/2019**

## ETN2126 – INFORMATION THEORY AND ERROR CODING

(TE, MCE)

02 MARCH 2019
2:30 p.m. – 4:30 p.m.
(2 Hours)

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**INSTRUCTIONS TO STUDENTS**

1. This Question paper consists of 5 pages with **FOUR** (4) Questions only.
2. Attempt ALL **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

## Question 1

(a) Four symbols, S = {$s_0$, $s_1$, $s_2$, $s_3$} can be transmitted from a discrete memoryless source (DMS) with corresponding probabilities of {0.2, 0.3, 0.1, 0.4}, respectively.

(i) Briefly state Shannon's Source Coding Theorem.

[2 marks]

(ii) Calculate the source entropy, H(S), of the DMS given above.

[3 marks]

(iii) Calculate the entropy for the extended DMS source, $H(S^4)$.

[3 marks]

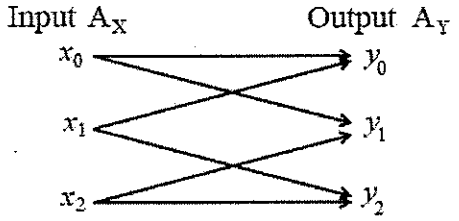
(iv) Is the H(S) in Q1(a)(ii) the maximum value? If not, calculate the maximum value for H(S) that the DMS above can obtain.

[3 marks]

(v) Is it possible for H(S) to be zero? If yes, explain your answer.

[3 marks]

(b) A discrete memoryless channel is shown in Figure Q1 together with its channel matrix. Furthermore, the inputs {$x_0$, $x_1$, $x_2$} have probabilities of {0.5, 0.3, 0.2}, respectively.




$$p(y_k|x_j)=\begin{bmatrix}0.5 & 0.5 & 0\\ 0.5 & 0 & 0.5\\ 0 & 0.5 & 0.5\end{bmatrix}$$

**Figure Q1**

(i) Calculate $H(A_X)$, $H(A_Y)$ and $H(A_Y|A_X)$.

[9 marks]

(ii) Using values from Q1(b)(i), compute the mutual information of the channel.

[2 marks]

Hint: $$H(A_Y \mid A_X)=\sum_{k=0}^{K-1}\sum_{j=0}^{J-1} p(y_k \mid x_j)p(x_j)\log_2\left[\frac{1}{p(y_k \mid x_j)}\right]$$

**Continue.....**

## Question 2

(a) The probabilities of the DMS symbols $\{s_0, s_1, s_2, s_3, s_4, s_5\}$ are given as {0.24, 0.06, 0.06, 0.40, 0.12, 0.12}, respectively.

(i) Design a Huffman code for this source so that the variance of the codeword length is kept minimal.

[6 marks]

(ii) Draw the decision tree of the code obtained in Q2(a)(i) above.

[4 marks]

(iii) Assume that the extended DMS of Q2(a) is transmitting at 100 k blocks/s. If the required information rate is at least 600 kbps, what should be the minimum degree of source extension to achieve such an information rate?

[5 marks]

(b) Consider a (7, 4) Hamming code with parity-check matrix given as:

$$H = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Find the original transmitted codeword if the received codeword is 1011011 and only one error has been made.

[4 marks]

(c) Consider the (15, 11) cyclic code generated by $g(D) = 1 + D^2 + D^4$. Find the code polynomial using polynomial division (in systematic form) for the message $m(D) = D^8 + D^{10}$.

[6 marks]

**Continue.....**

## Question 3

(a) Consider a rate $r = 1/2$, constraint length $K = 3$ convolutional encoder with generator polynomials:

$$g^{(1)}(D) = 1 + D + D^2$$
$$g^{(2)}(D) = 1 + D^2$$

(i) Draw the block diagram of the encoder.

[5 marks]

(ii) Find the codeword corresponding to the information sequence 10011.

[5 marks]

(iii) Draw the trellis diagram for an information sequence of 5 bits length.

[5 marks]

(iv) Suppose that the coded data is transmitted over a binary symmetric channel with transition probability $p = 0.01$. With the trellis diagram obtained in Q3(a)(iii), use the Viterbi algorithm to decode the received sequence $\mathbf{r}$ = (00, 01, 01, 00, 00, 10, 11), where the first pair to enter the decoder is 00. Highlight the final surviving path in the trellis diagram.

[7 marks]

(b) The structure of a convolutional code is fundamentally different from the structure of a block code. Briefly explain the difference. When is convolutional code preferred over block code?

[3 marks]

**Continue.....**

## Question 4

(a) Modulation is an important component in digital transmission.

(i) Briefly describe the role of a carrier wave in modulating the baseband signal.
[4 marks]

(ii) Explain how the baseband signal is modulated onto the carrier wave in the following techniques: Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK).
[6 marks]

(iii) Trellis coded modulation (TCM) combines convolutional encoding with modulation. State the key idea behind this integrated coding and modulation approach.
[2 marks]

(b) Consider a TCM system that uses a rate ½ convolutional encoder to encode one information bit while the second information bit is left uncoded. The generator polynomials for the convolutional encoder are given as follows:

$$g^{(1)}(D) = 1 + D^2$$
$$g^{(2)}(D) = D$$

(i) Draw the block diagram of the TCM system which consists of the convolutional encoder and the signal mapper.
[5 marks]

(ii) Draw the state transition diagram.
[4 marks]

(iii) Draw the trellis diagram.
[4 marks]

**End of Paper**